HUNTOON

Power Required to Run Machine Tools

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POWER REQUIRED TO RUN MACHINE TOOLS

BY

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THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

HARRY ALEXANDER HUNTOON

ENTITLED POWER REQUIRED TO RUN MACHINE TOOLS

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE

OF Bachelor of Science in Mechanical Engineering

L. P. Breckenridge

HEAD OF DEPARTMENT OF Mechanical Engineering

POWER REQUIRED TO RUN MACHINE TOOLS.

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In order to measure the power required to drive a machine tool it is necessary to have an intermediate device which serves as an instrument to measure the work delivered to the machine tool in a specified time. The most common type of instrument used for this purpose is what is called a Dynamometer.

Kent's Mechanical Engineering Pocket Book gives the following classification of dynamometers: (1) Traction Dynamometers used for determining the power required to pull a car or other vehicle; (2) Brake or Absorption dynamometers in which the power of a rotating shaft or wheel is absorbed or converted in to heat by the friction of the brake; (3) Transmission Dynamometers in which the power in a rotating shaft is measured during transmission through a belt or other connection to another shaft without being absorbed.

A Traction Dynamometer could not be used in the line of work taken up by this thesis as it lends itself to other purposes than the consideration of machine tools. A Brake or Absorption Dynamometer deals with a condition such that the power developed is absorbedin the instrument and is used more for calibrating prime movers.A Transmission Dynamometer seems to be the only

type of instrument that could be used along the line of this thesis since it acts as an intermediate mechanism in the system between the source of power and the machine involved in the test.

Transmission Dynamometers can be divided into two distinct classes; (1) Differential Dynamometers and (2) Belt Dynamometers. While there are many different kinds of transmission dynamometers they all involve one of two principles.

The principle involved in the differential dynamometer is based upon the action of a train of four mitre gearsall of which are fixed to the same casing. If we denote the driving gear by A and the driven gear by B, then the axis of A and B are at right angles with each other and B turns on a shaft which acts as a lever arm from which the power being transmitted is measured. The gear C meshes with B and its shaft has the same axis as that of A. The gear D runs upon the same shaft as B. and meshes with C and A.

The action of the belt dynamometer is such that a single belt running off of a driving pulley under an idler, thence over the driven pulley and under another idler back to the driver. The idlers, attached to the same rigid frame are so set that the angle formed by the belt lines of on-going and off-running belt portions is 120°. The frame carrying the idlers communicates with a piston operating in an oil-cylinder, the pressure exerted by the resultant belt tensions being thus obtainable .

The dynamometer used in this thesis was one of the belt

type and was designed and built by F. L. Drew, B. S.,1904, University of Illinois, submitted as a thesis.

The principle of this dynamometer can be readily understood by referring to Plate I. For convenience in construction we always have the lower belt portion the tighter one. If the angle formed by the belt as it passes over the idler is maintained at 120°, then the forces acting in the plane of the idler axes are equal to the tensions in their respective portions of the belt. These we may denote by C' and C . Let us consider one idler only and for convenience take the lower one. The forces acting along the belt are A' and B' , their lines of action making an angle of 120° with each other and also at 120° with the plane containing the idler axes. Denote the force which holds A' and B' in equilibrium by C'. As each force acts so as to form an angle of 120° with the remaining two of the system and A' and B' must be equal as they are in the same belt, there being no force necessary to turn the idler, the force C' must be equal in magnitude to A' and also equal to B' , a conclusion easily arrived at either graphically or analytically . The line of action of C' is such that it bisects the angle of 120° formed by the lines of action of A' and B' and of a sense that it may have a component opposed to A' and B'. A similar line of reasoning establishes the conclusion that when considering the other idler, which is acted upon by the forces denoted by A and B, the latter are held in equilibrium by a force C equal to A or B and the latter two representing the belt tensions in the portions of

the belt passing over the idler in question.

Let us denote the forces which make possible the forces C' and C as acting upon the idler frame by R' and R respectively. R' must necessarily be equal in magnitude to C', but opposed in sense; a similar relation holds for R and C .

Expressing algebraically, the following relations regarding magnitudes:

$$A'=B'=C'=R' \quad \text{and} \quad A=B=C=R.$$

As the lower portion of the belt is the tighter one, then R' is greater than R and their difference will be the difference in belt tensions. As the two idlers are attached to the same frame, the two resultant of belt tensions, R' and R , will subtract one from the other . The difference represented by R'-R must then be supplied by a force external to the frame in a sense opposed to the resultant of the entire system of forces acting upon the idlers and frame. This external force must be equal in magnitude to the difference in belt tensions. The force being known and also the travel of the belt in feet per minute we are able to obtain the horse power that is being transmitted by the dynamometer.

In the thesis of F.L Drew mentioned above an explanation can be found of the method of transmitting the difference of belt tensions by means of oil to the pistons of an ordinary steam engine indicator, the pencil point of the indicator drawing a graphic record of this pressure on a moving chart. The several

considerations of oil-cylinder piston diameter , paper travel, to run speed ratio etc. , are also taken up in detail in the same place.

O B J E C T .

When the investigation of this subject was first undertaken by the writer, the object in view was to use the dynamometer as it was originally built and to make tests on one particular kind of machine tool, for the purpose of determining the power required to drive a certain machine under different conditions and also of different sizes of the same kind of machine tool. After looking over the dynamometer and some of the previous tests , it was found necessary to overhaul the former before further satisfactory tests could be attempted. This changed the original plans to a certain extent, for the time expended in ove over hauling the dynamometer would have to be taken from that which was originally intended for tests. The object of this thesis , then, asit was taken up was to perfect the dynamometer so far as possible and to calibrate for different speeds.

A P P A R A T U S.

The most important piece of apparatus used in the work was the dynamometer. As has been stated previously its condition was not such that it could be relied upon for obtaining accurate results. The problem of keeping the belt on the pulleys for variable speeds had never been successfully solved. After experimenting for some time it was found that by crowning the idlers, putting the pulleys in line with each other, and replacing the old belt by a new one this difficulty was overcome.

The device which was used to keep the frame of the idlers under control, consisted of a yoke of iron fastened rigidly to the frame of the dynamometer. It was also fastened rigidly to the frame of the idlers. This did not allow the idlers to have a free motion of working up and down on the piston of the oil-cylinder as they should have had. So flanged rollers were placed on the shaft of the upper idler and allowed to run up and down in guides which were fastened to the frame. These guides were constructed so as to to be capable of adjustments in all directions, thus allowing the idlers to be easily alligned . The arrangement may be seen in the photographs on page 8..

One of the other defects encountered was in the paper motion device shown by drawing on Plate II. It consisted of the three drums A, B, and C turning on spindles which were fasten ed to the brass table F. The drum B was turned by a small worm shaft which turned at a fixed ratio with the belt pulleys. This

drum was the one upon which the continuous chart was to be taken and as it was the only one which could run at a constant angular velocity ratio with the pulleys it should have regulated the travel of the paper. The drum A was the one upon which the roll of blank paper was placed while drum C collected it after the chart was taken. The pull of the paper turned the drum A , but hte drum C was t urned by means of the knurled disk D. The disk was on a shaft running under the table F and was turned by means of gears from the worm shaft.

The main difficulty with the device as described was that the drum B, was unable to insure the desired ratio of paper travel to pulley rim speed. At times the winding drum C would overcome the frictional grip of the drum B on the paper and the paper would creep ahead while at other times the surface B would creep ahead of the paper. This condition was due to the small frictional coefficient as between the paper and drum surface of B and also to the small arc of contact. The amount of relative motion between the surface of B and the paper which should have been zero if properly operating, depended also upon the size of the paper roll on the winding drum C; a small roll resulting in the paper lagging, and a large roll causing the paper to creep This latter factor in the problem prevented the establishment of a satisfactory coefficient to be used in connection with the paper travel and compelled the remodelling of the paper moving device.

The new paper moving device built to overcome this dif-

ficulty enumerated above is shown in Plate III.

By placing two drums side by side as shown by drums A and B, Plate IV, and giving each drum a positive motion by treating the single worm-shaft E, it is possible to obtain a firm grip on the paper which is led between the rolls , this insuring the desired paper travel. It is to be noted that the single worm-shaft E, carries a left hand and a right hand worm of equal pitch each engaging with a gear fastened to each of the drums A and B; this arrangement compels each angular velocity magnitude of A and B to be equal but in sense to be opposite. The paper takes the course shown by the red line being first placed upon the drum D . The accumulating drum C is driven by the friction plate G, which is placed between two metal plates, the lower one being fastened to the shaft and the other being fastened to the drum. The tension carried upon the paper may be regulated by a thumb nut at the top of the shaft as it bears upon the spring washer. The worm-shaft being driven by direct positive motion, the paper travel must have a fixed ratio with that of the pulley rim travel.

The old device by which the operator of the dynamometer held a check on the angles of the belt was somewhat uncertain. It consisted of the pointer, shown in Figure 1, of Plate IV, which was screwed to the base of the machine. The pointer was placed opposite to a mark on the frame of the idlers when the belt was placed so as to make proper angles. This was replaced by the system of levers, shown in Figure 2, Plate IV.

The standard F was screwed into the frame of the idlers while G was screwed into the frame of the machine. The lever arms of D being one to one while those of B are as two to one the travel of the point C is twice that of F. Thus when the belt is set at the proper angles the pencil in C is set on the base line of the chart and any decrease in volume of the oil can be readily seen while in operation, and can be replaced by forcing new oil into the pipe system by means of the screw plunger provided for this purpose.

METHOD OF CONDUCTING TESTS.

After overhauling the dynamometer it was necessary to calibrate it for different speeds and obtain the relation between the B.H.P. absorbed after transmission and the H.P. indicated on the chart as being transmitted through the machine . This was brought about by belting from one shaft of the dynamometer to a high speed steam engine , and placing a Prony brake on the other shaft.

Tests were run in this way at different speeds of the machine, keeping the R.P.M. as near constant as possible within each test. At each speed data was taken for several loads. The tests were all run a duration of one minute and in each case obtaining the R.P.M. . The brake was set so as to obtain a certain scale reading which was always kept constant throughout each test. From this data the B.H.P. was computed and also the travel of the belt in feet per minute . This being known together with the mean pressure on the oil cylinder which is obtained from the indicator chart, the I.H.P. may be obtained.

In order to determine the ratio of the belt to the paper travels, the lengths of several charts were measured and corresponding lengths of belt travel were computed. Then by dividing the belt travel in feet per minute by the paper travel in inches per minute this constant may be computed. The constant thus obtained does away with taking the R.P.M. while taking tests

PLATE I.

PRINCIPLE OF BELT DYNAMOMETER.

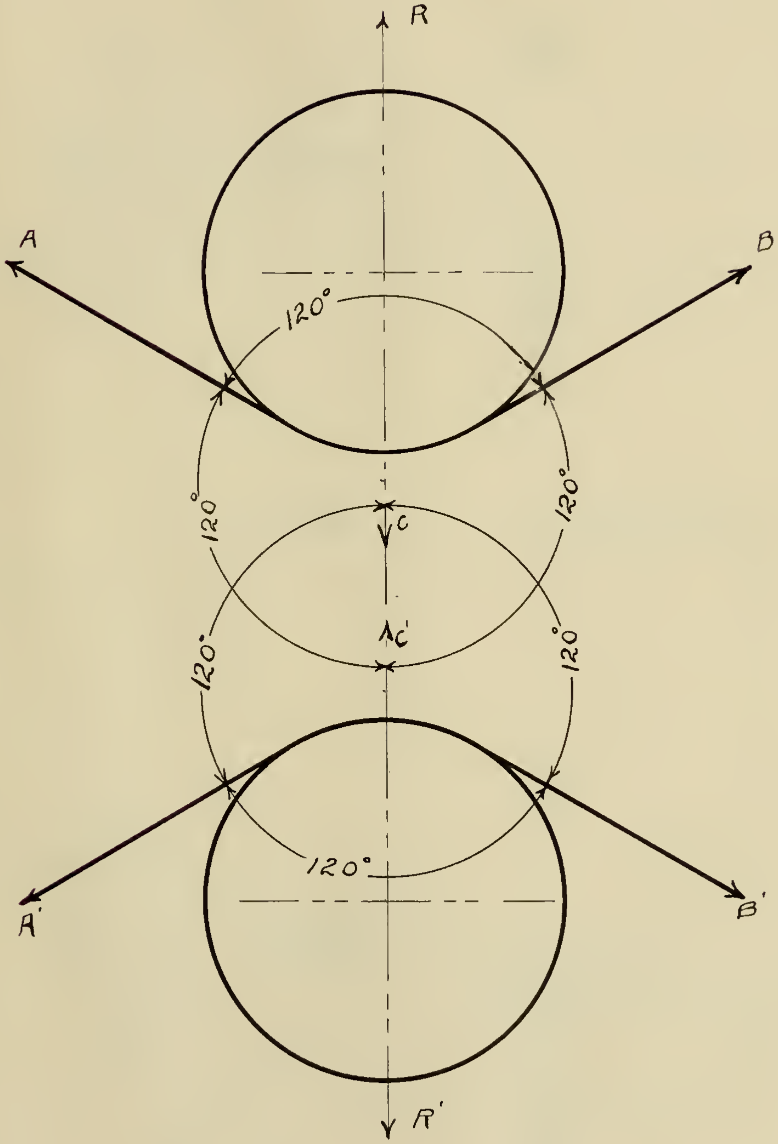

PLATE II.

OLD PAPER MOTION DEVICE ON DYNAMOMETER.

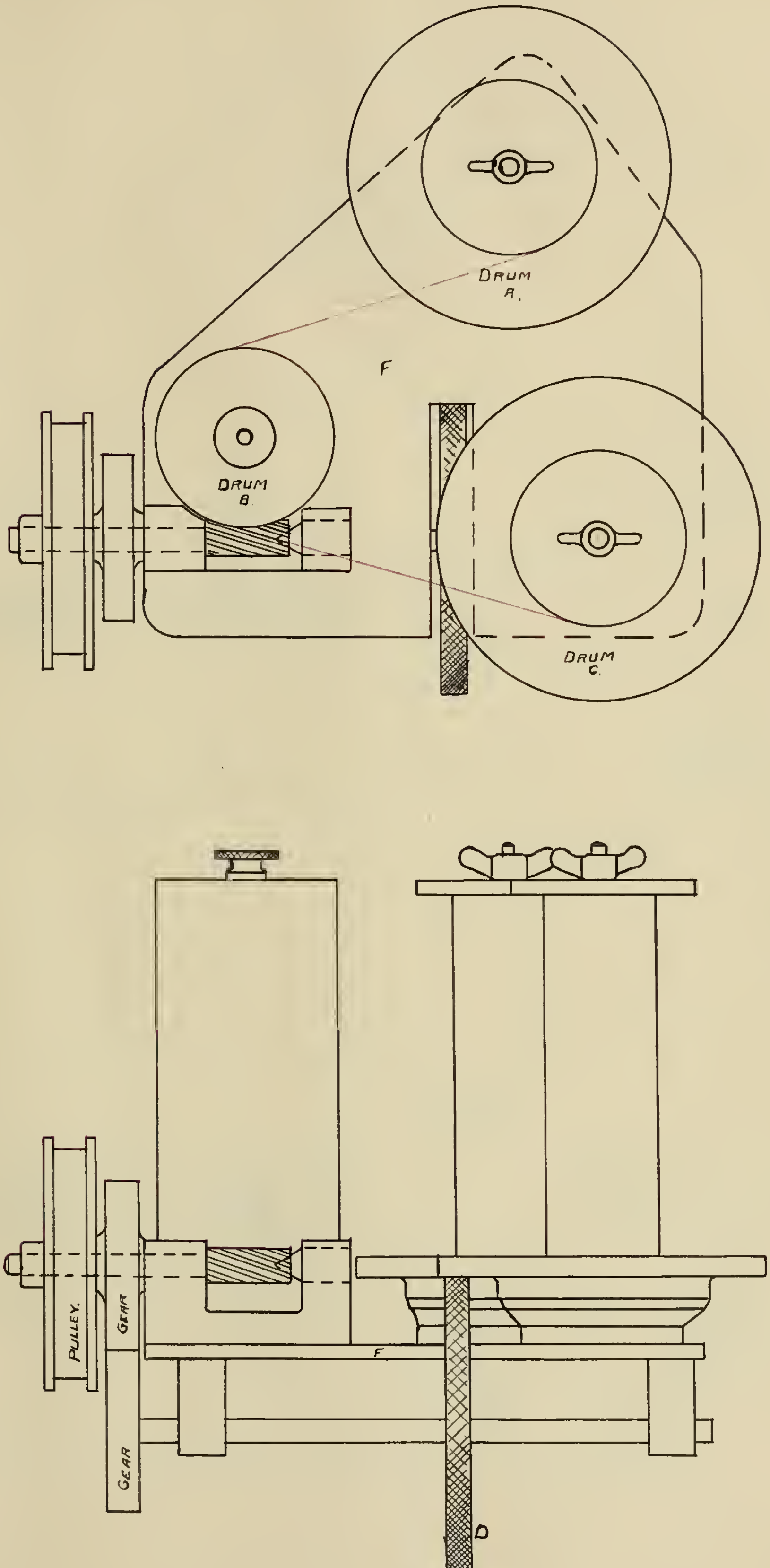

PLATE. III.

NEW PAPER MOTION DEVICE FOR DYNAMOMETER.

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H. A. HUNTOON.

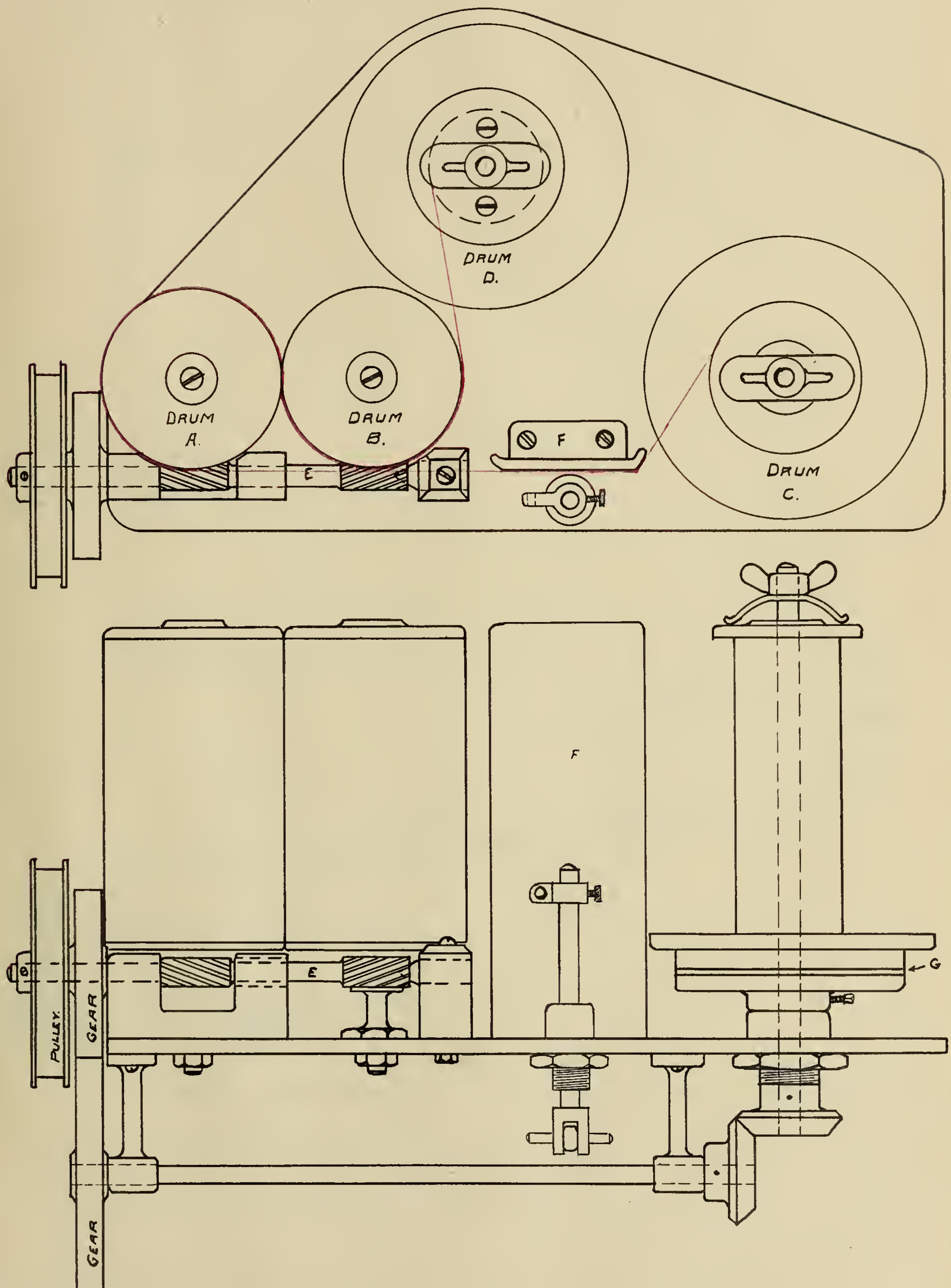


PLATE IV.

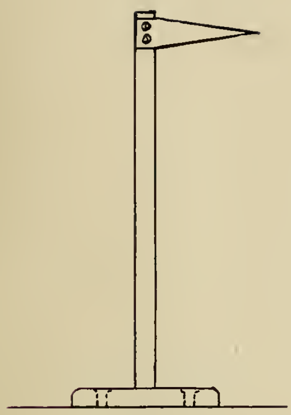


FIG. 1
OLD POINTER.

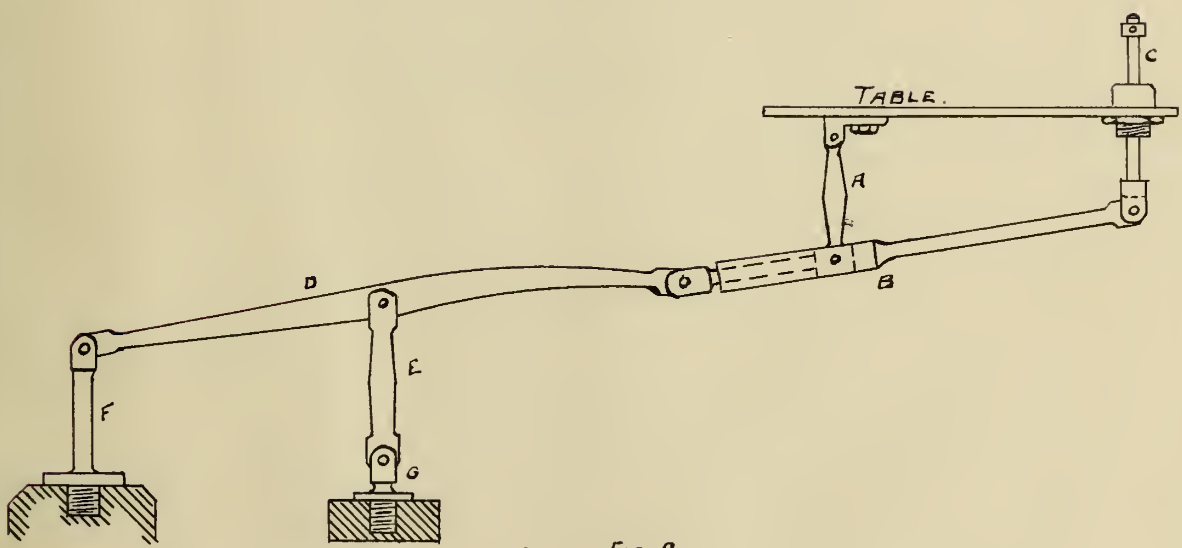


FIG. 2.

NEW POINTER DEVICE.

DATA.
FOR
CALIBRATION OF
DYNAMOMETER.

TABLE No. 1.

CALIBRATION DATA FOR DYNAMOMETER.

No. of Test.	Duration of Test in Sec.	R.P.M.	Brake Scale Reading.	Belt Travel in Feet per Min.	Mean Pressure on Oil Cyl. in Lb.	I.H.P.	B.H.P.
1	2	3	4	5	6	7	8
1	60	129	5	469.5	17	.24	.318
2	"	140	5	509.6	17	.26	.345
3	"	88	10	320.5	27	.262	.434
4	"	80	10	291.2	26	.23	.394
5	"	110	20	401	44	.535	1.09
6	"	106	20	386	44	.515	1.05
7	"	194	5	706	7.5	.16	.477
8	"	185	5	673.5	7.5	.153	.455
9	"	219	10	796	26.5	.64	1.08
10	"	223	10	811	27	.66	1.10
11	"	222	15	807.5	36.5	.894	1.64
12	"	223	15	811.	35	.86	1.65
13	"	318	20.4	1154	51.5	1.8	3.2
14	"	335	20.4	1219.5	50.	1.84	3.37
15	"	316	13.5	1150.	42.5	1.48	1.95
16	"	319	13.5	1162.	39.	1.37	1.97
17	"	294	6.7	1070	19.5	.63	.97
18	"	318	6.7	1158	19.5	.68	1.05
19	"	408	10.1	1487	27.5	1.24	1.99
20	"	412	10.1	1499.68	26.5	1.2	2.01
21	"	428	5.1	1559.	12.5	.59	1.08
22	"	394	5.1	1434.	10.5	.46	.99
23	"	397	2.6	1445.	7.	.306	.509
24	"	410	2.6	1493.	8.5	.384	.525

TABLE No.2.

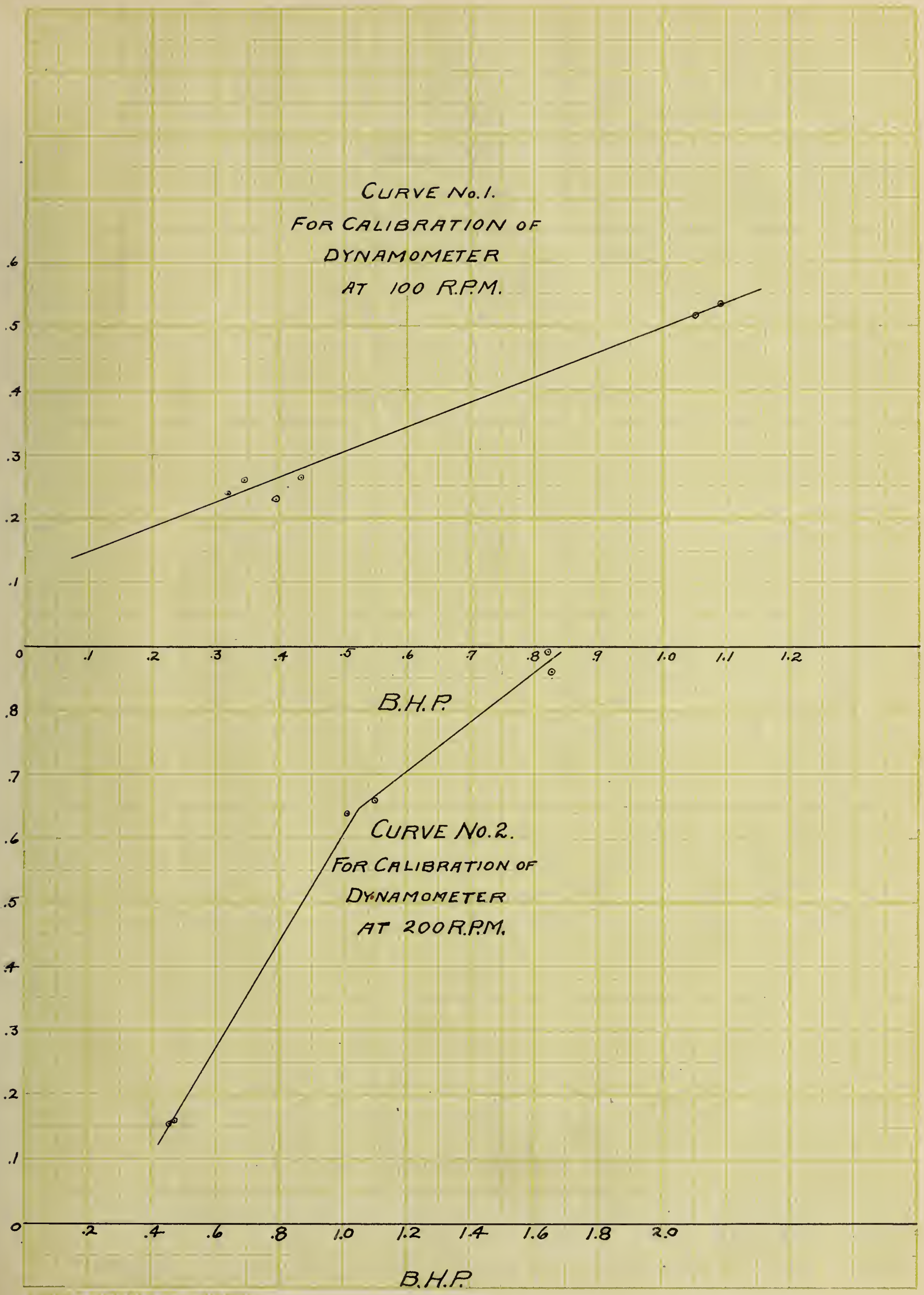
CALIBRATION DATA FOR DYNAMOMETER.

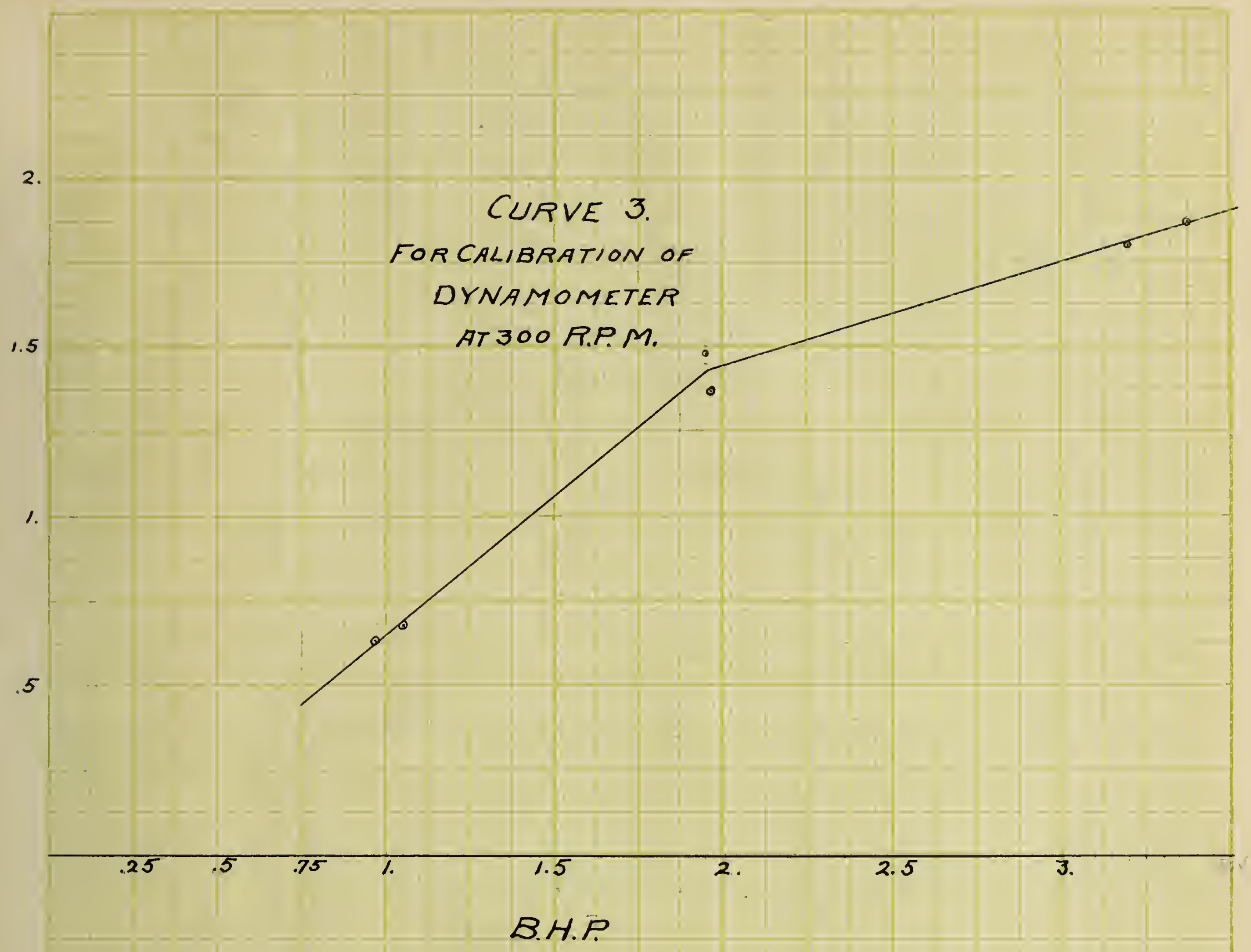
No. of Test.	Duration of Test in Sec.	R.P.M.	Brake Scale Reading	Belt Travel in Feet per Min.	Mean Pressure on Oil Cyl. in Lb.	I.H.P.	B.H.P.
1	2	3	4	5	6	7	8
25	60	519	8.1	1889.16	25.5	1.46	2.07
26	"	519	8.1	1889.16	25.5	1.46	2.07
27	"	533	12.1	1940.12	31.5	1.85	3.18
28	"	526	12.1	1914.64	30.	1.74	3.14
29	"	514	4.1	1871.	6.5	.38	1.08
30	"	504	4.1	1835.	6.5	.362	1.04
31	"	595	10.2	2165.	23	1.51	2.99
32	"	595	10.2	2165.	31.5	2.06 *	2.99
33	"	609	13.8	2218.	36.5	2.45	4.14
34	"	607	13.8	2208.	35.	2.55	4.13
35	"	606	7.	2205.	19.	1.28	2.09
36	"	618	7.	2250.	19.	1.30	2.13
37	"	700	3.	2548.	5.	.386	1.07
38	"	690	3.	2512.	5.	.38	1.02
39	"	697	9	2536.	24.	1.85	3.09
40	"	704	9	2561.	24.	1.87	3.12
41	"	725	15	2638.	39.5	3.16	5.35
42	"	725	15	2638.	39.5	3.16	5.35
43	"	803	2.5	2921.	6.	5.44	.99
44	"	822	2.5	2992.	6.	5.45	1.01
45	"	794	7.5	2888.	18.	1.57	2.94
46	"	783	7.5	2850.	18.	1.55	2.9
47	"	773	12.5	2814.	33.	2.814	4.76
48	"	776	12.5	2824.	34	2.9	4.8

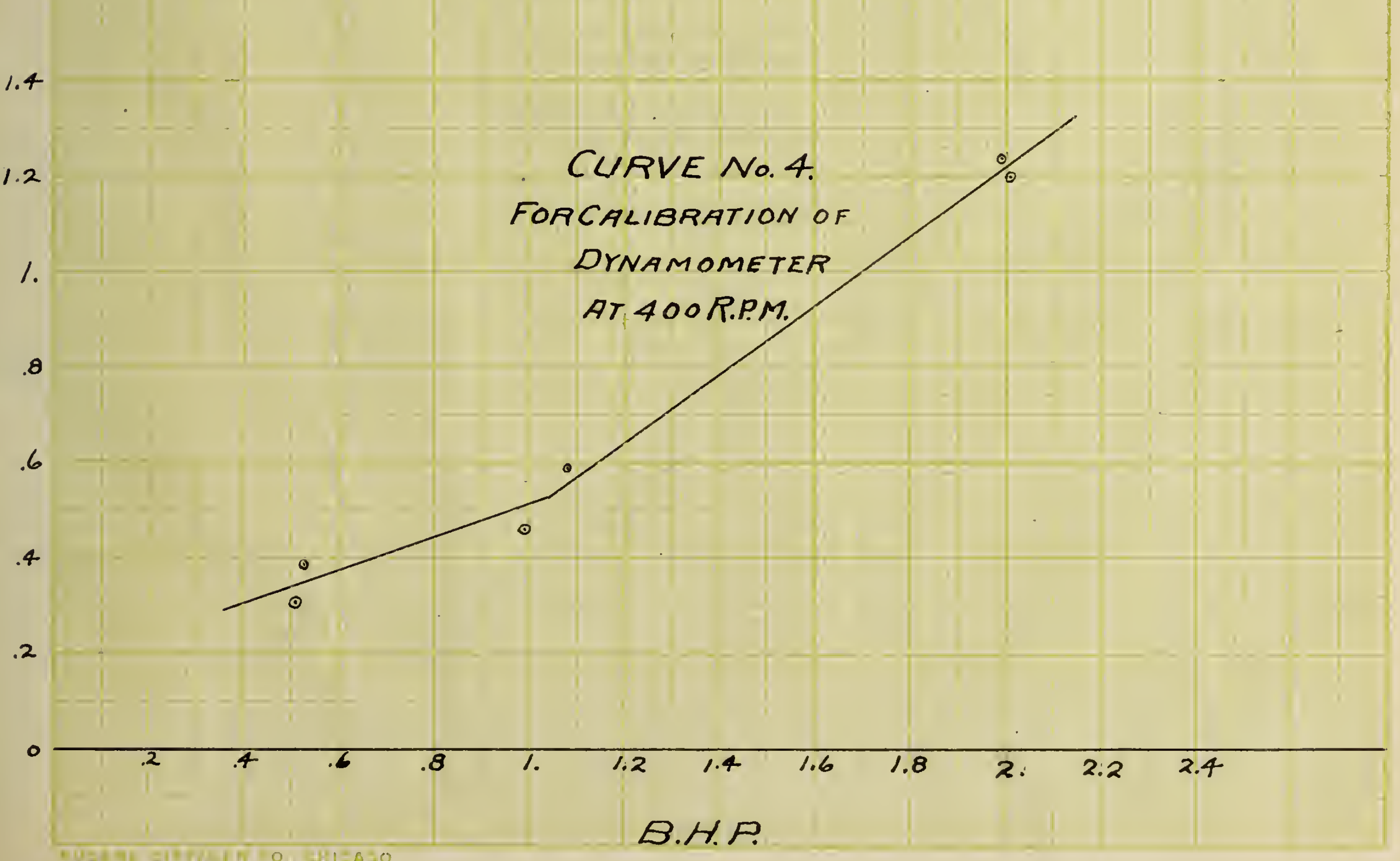
CALIBRATION CURVES.

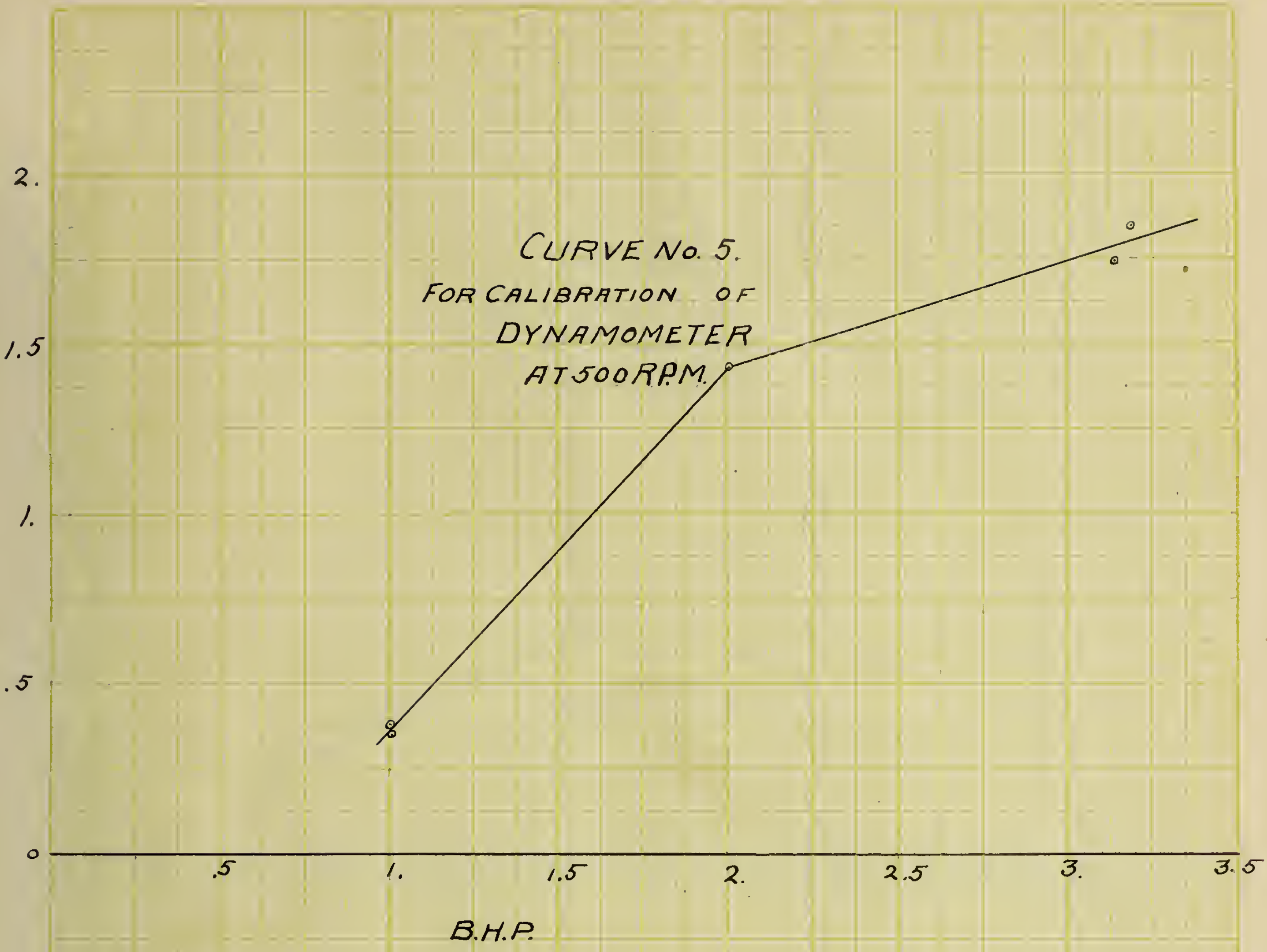
OF

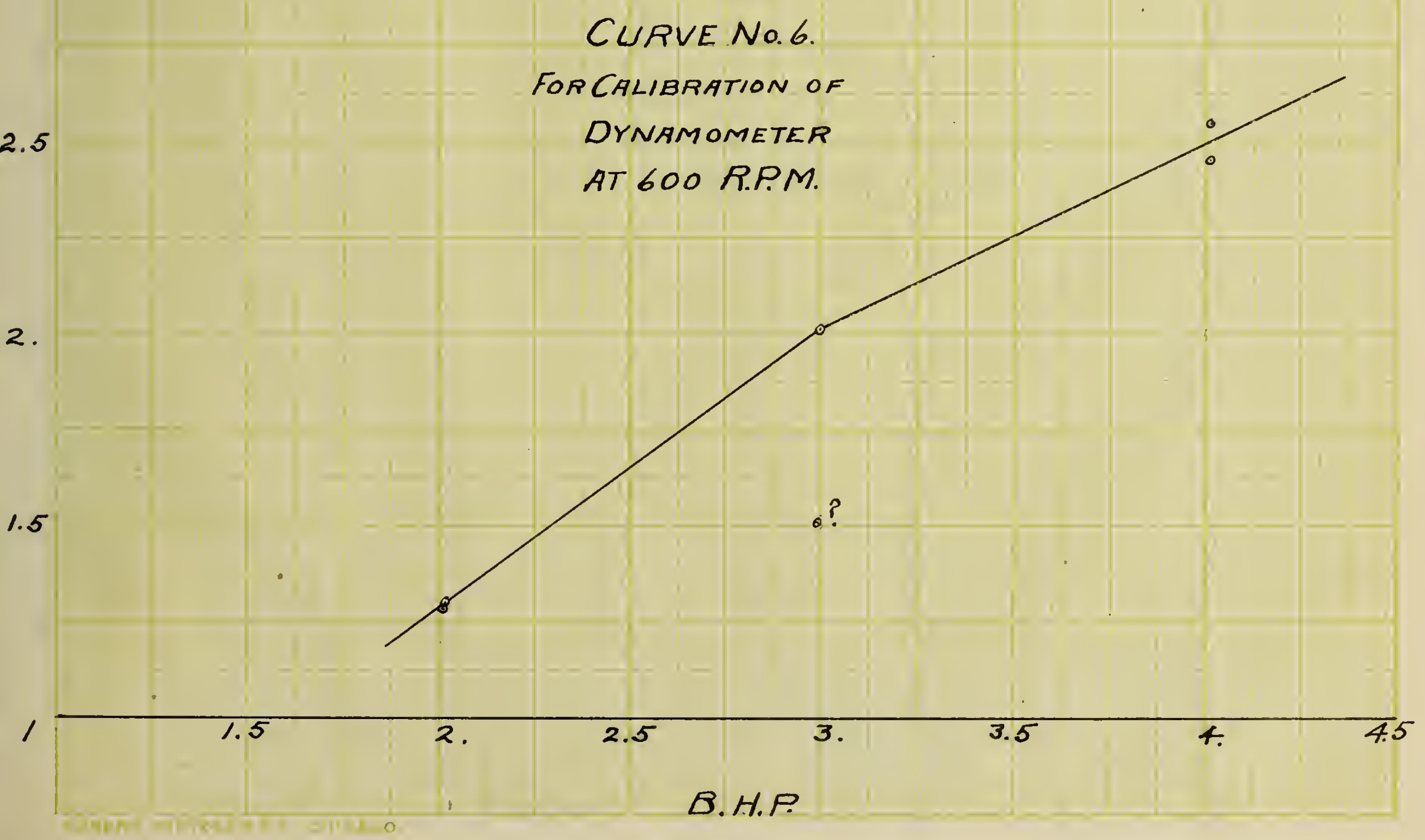
DYNAMOMETER.

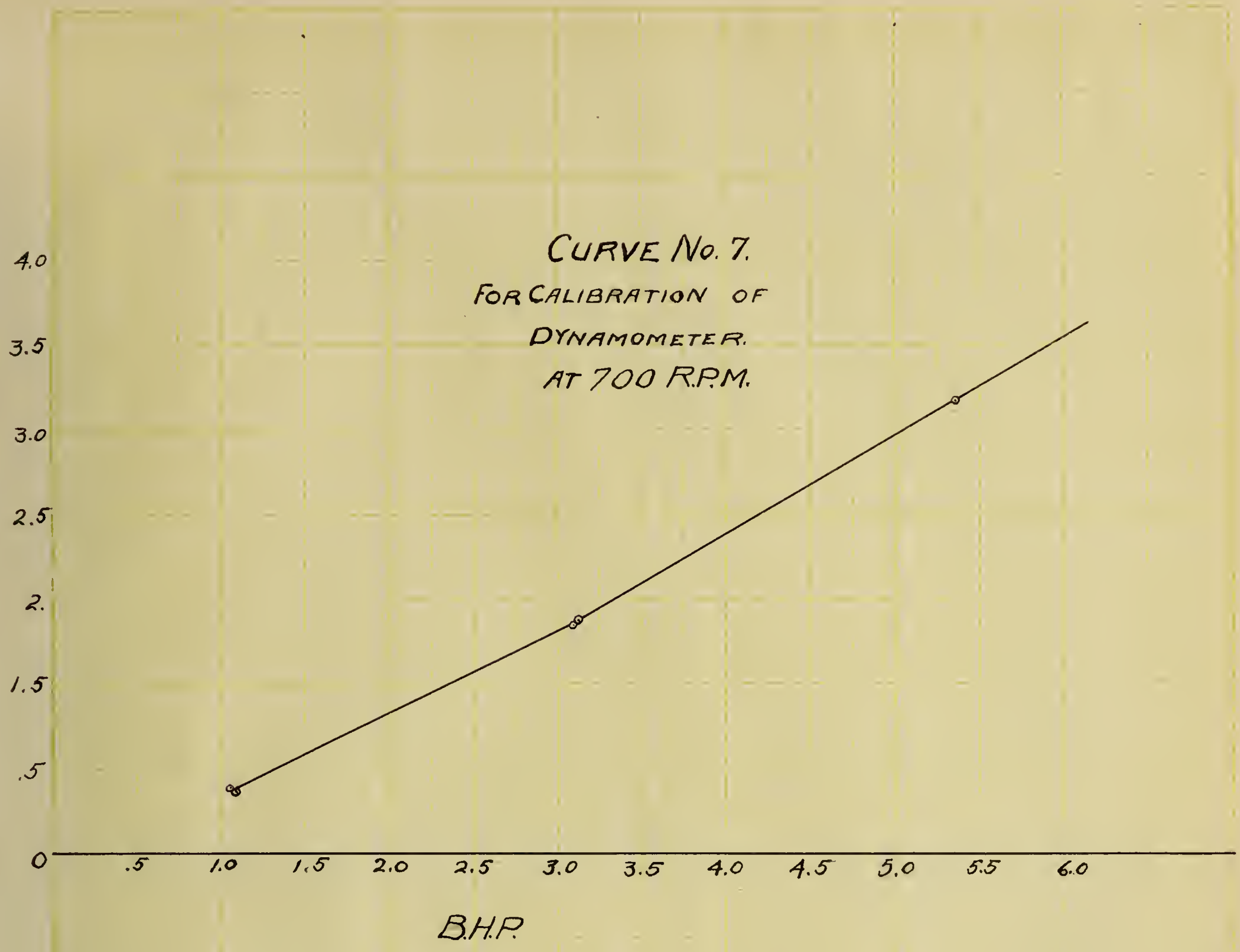

CURVE No. 1.
FOR CALIBRATION OF
DYNAMOMETER
AT 100 R.P.M.
.1
.2
.3
.4
.5
.6
0
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0
1.1
1.2
B.H.P.
CURVE No. 2.
FOR CALIBRATION OF
DYNAMOMETER
AT 200 R.P.M.
.1
.2
.3
.4
.5
.6
.7
.8
0
.2
.4
.6
.8
1.0
1.2
1.4
1.6
1.8
2.0
B.H.P.

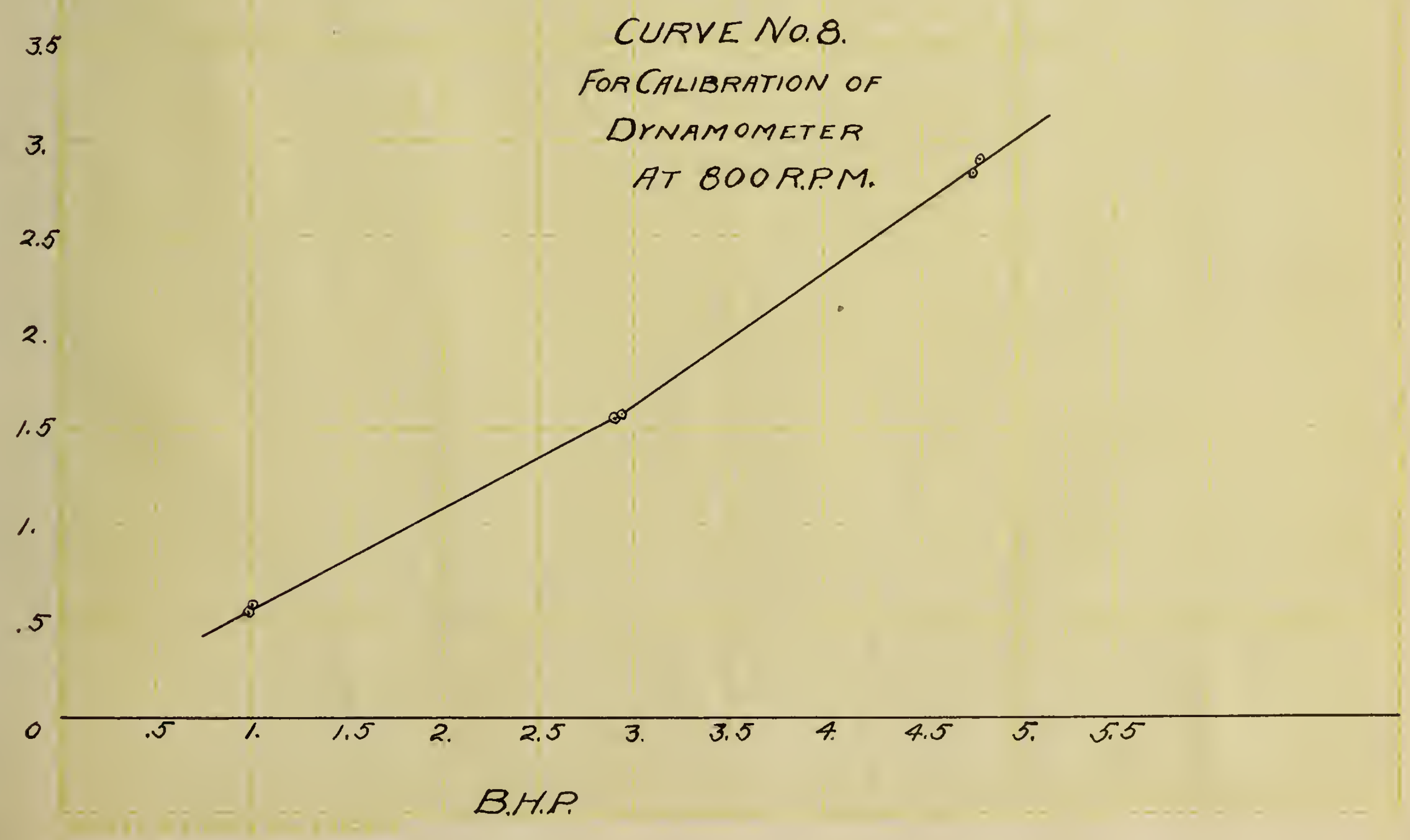

CURVE 3.
FOR CALIBRATION OF
DYNAMOMETER
AT 300 R.P.M.
2.
1.5
1.
.5
.25
.5
.75
1.
1.5
2.
2.5
3.
B.H.P.


CURVE No. 4.
FOR CALIBRATION OF
DYNAMOMETER
AT 400 R.P.M.
1.4
1.2
1.
.8
.6
.4
.2
0
.2
.4
.6
.8
1.
1.2
1.4
1.6
1.8
2.
2.2
2.4
B.H.P.


CURVE No. 5.
FOR CALIBRATION OF
DYNAMOMETER
AT 500 R.P.M.
2.
1.5
1.
.5
0
.5
1.
1.5
2.
2.5
3.
3.5
B.H.P.


CURVE No. 6.
FOR CALIBRATION OF
DYNAMOMETER
AT 600 R.P.M.
2.5
2.
1.5
1
1.5
2.
2.5
3.
3.5
4.
4.5
B.H.P.


CURVE No. 7.
FOR CALIBRATION OF
DYNAMOMETER.
AT 700 R.P.M.
4.0
3.5
3.0
2.5
2.
1.5
.5
0
.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
B.H.P.


CURVE No. 8.
FOR CALIBRATION OF
DYNAMOMETER
AT 800 R.P.M.
3.5
3.
2.5
2.
1.5
1.
.5
0
.5
1.
1.5
2.
2.5
3.
3.5
4.
4.5
5.
5.5
B.H.P.